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The Colorimetric Estimation of Phosphorus in Acid Soil Extracts.

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In a recent number of this Journal Greenstreet[1] described an attempt to apply Atkins[2] modification of the Denigès[3] method to acid soil extracts. He worked with one soil and found colorimetric results to be approximately 25% lower than those obtained by gravimetric methods. He also found that ferric iron in the proportion of 15Fe : 1PO_4 did not seriously interfere with colour development, reducing the reading only 6%. The writer then took up the problem and found that Greenstreet had worked with a soil containing less iron than usual, the majority of our soils giving up more iron to strong acids than the Serdang soil used by him, 10—15% Fe_2O_3 and .02—.03% P_2O_5 being common figures while 50% Fe_2O_3 and .03% P_2O_5 may be encountered. Ratios such as these are far outside the limits of non-interference and render direct application of the method impossible.

Since ferrous iron does not interfere with colour production, the next step was to work out a suitable method of reduction.

Meanwhile Denigès[4] published another paper, describing a method of combined reduction and colour development by boiling the soil extract with molybdate sulphuric reagent in presence of copper turnings. Very unsatisfactory results were obtained by the writer and after several trials this method was abandoned, and attempts to bring about preliminary reduction resumed. Methods tried included reduction by all likely metals and by SO_2. Zinc reduction proved to be the most satisfactory.

The real difficulty was found to lie not in reduction, but in the subsequent regulation of acidity. Denigès[3] and Gilbert and Smith[5] have pointed that colour development is exceedingly sensitive to hydrogen ion concentration, too low a concentration permitting direct action between stannous chloride and ammonium molybdate, while too high a concentration causes bleaching or non-development of the phosphate colour.

To ensure clean metallic reduction there must be an excess of strong acid present, if now ammonia or alkalies are used to remove the excess, failing undesirably great dilution, local precipitates are obtained which are troublesome to redissolve, and in which the ferrous hydroxide undergoes rapid re-oxidation.

Eventually it was found that the excess of strong acid could best be removed by addition of ammonium or sodium acetate, thus avoiding the formation of precipitates. Acetates in small quantity and at the proper pH value do not interfere with colour development—as shown in Table I.

At first brom-phenol blue was used as an indicator on addition of acetate; this gave results of the correct order, but the colour faded rapidly. The cause of this fading is undoubtedly too low a hydrogen ion concentration due to buffering in the test solution.

It was then found that if thymol blue in its acid range was used as indicator a good and permanent colour was developed.

The procedure finally adopted is as follows:—

A quantity of extract equivalent to 1 grm. of soil (prepared by any of the usual methods) from which organic matter, any large quantity of silica and nitric acid have been removed by gentle ignition, is taken up in a small quantity of strong HCl, and if necessary filtered and any residue washed, 2—3 grs. of pure granulated (lump) zinc and 3 or 4 ccs. of 1 : 1 HCl are added and the whole gently warmed. When all yellow colour has disappeared and only the faintest yellow brown colour is given to a "spot" of ammonium thiocyanate, and before the whole of the acid present has been used up by the zinc (i.e. while hydrogen is still being freely evolved) the solution is rapidly filtered through a light cotton wool plug into a 100 ccs. graduated flask and made to the mark.

To an appropriate aliquot (40 ccs. for our mineral soils with a P_2O_5 content of .02—.03%) in a 50 cc. graduated flask or cylinder is added 3 drops of thymol blue (.04%) and then 5 M. ammonium acetate drop by drop until the pink colour just begins to fade—if carried too far dilute HCl must be slowly added till the colour just reappears. Then is added 1 cc. of Atkins' Reagent A and 3 drops of Reagent B, the whole made to the mark, shaken and allowed to stand at least 1½ minutes before reading. Up to 15 minutes, there are negligible changes in the standard and test solutions. If the aliquot taken gives too deep a colour (*v. inf.*), a repetition must be made with a smaller quantity.

An equal number of drops of thymol blue must be added to 50 ccs. of standard to secure a good match in the colorimeter.

Reading.—Differences of 0.02 mgrs. P_2O_5 can easily be seen in a series of 50 cc. Nessler cylinders containing 0.02 to 0.12 mgs. P_2O_5 and comparison with these would be sufficient for practical purposes; it is however easier and more expeditious to use a colorimeter.

The writer uses 60 m.m. cups in a Kober-Klett and makes two readings, starting with the test lighter and then darker than the standard. At the optimum colour for reading it is easy without especial care to get readings to agree within 0.75 of a division, and it is a waste of time to strive for greater refinement. Assuming the test solution and standard to be approximately equal and the latter to be set at 40 and to contain 0.1 mgs. P_2O_5 in 50 ccs. an error of as much as 2 divisions would give an error of only 5% in the result.

Reading is easier as the colour intensifies, unfortunately at concentrations greater than .20 mgs P_2O_5 per 50 ccs. colour development is uncertain and no longer directly proportional to concentration, even when stronger standards are used, *vide* Table I. There is in addition the difficulty of knowing whether sufficient stannous chloride has been added.

It has been found that solutions rather stronger than those used by previous workers, viz. 0.04—0.20 mgrs. P_2O_5 per 50 ccs. give good colour development and are, to the writer at any rate, much easier to read in the colorimeter. Within these concentrations, which by appropriate adjustment of aliquots, will cover any soil, only one standard, viz. 0.1 mgs. P_2O_5 per 50 ccs. is needed.

Table I shows also that a standard double the strength of that suggested gives rise to large errors even with low concentrations of P.

TABLE I.

All figures refer to mgr. P. per 50 cc. (1 mgr. P=2.29 mgr P_2O_5).

P taken.	Standard.	Setting of Standard.	P found.		
			Pure KH_2PO_4	KH_2PO_4 in N. NaCl	KH_2PO_4 & NH_4Ac.*
0.02	0.1	15	.032, .029, .028	.028	
		10	.025, .025	.028	
0.04	,,	25		.048	
		20	.048, .053	.048	
0.06	,,	40		.072	
		30	.067, .053	.072	
		20		.079	
0.08	,,	40	.081, .090	.092	
0.10	,,	40	.101	.101	
0.13	,,	,,		.115	
0.16	,,	,,		.132	
0.19	,,	50		.137	
0.22	,,	50		.142	
0.02	0.05	20	.024	.022	.020
0.04	,,	30	.043	.042	
0.05	,,	40			.050
0.07	,,	40			.068
0.08	,,	40	.080	.081	.087
0.10	,,	50	.090	.094	

*3 ccs. of 5M. in 50 ccs., adjusted with Hel and thymol blue.

In highly ferrugineous soils there may be a slight tone difference between extract and standard, the former being rather more violet than the latter—it is however quite easy to match intensity of illumination. Any grey colour may be ascribed to imperfect reduction or the presence of organic matter, and solutions showing such colours should be discarded. Attempts at adjustment by the use of Bismark brown or rough readings are sometimes successful, but more frequently lead to low results.

Reagents used.

Reagent A. 100 ccs. of 10% ammonium molybdate and 300 ccs. of 50% by volume sulphuric acid—stored in the dark.

Reagent B. 0.5 grm. tin, 5 drops 4% copper sulphate, 10 ccs. concentrated hydrochloric acid warm till dissolved, and dilute to 50 ccs.

Effect of Silica.

Silica is stated by Denigès to hinder colour development, the writer found however that 1 mgr. SiO_2 in 50 ccs. did not interfere with the estimation of 0.1 mgr. P_2O_5. This quantity of silica is unlikely to be exceeded in any ignited extract.

Analytical Results.

Results obtained on a variety of soils are given in Table II. The extracts (1 : 10) were prepared by the magnesium nitrate—aqua regia method[5]. Comparison results by the standard methods were made on 25 ccs. of the richer and 50 ccs. of the poorer soils.

Comparing the colorimetric results among themselves for any one soil there is a variation of about 20% between the highest and lowest results. This may appear large in comparison with the two and three place figures for P_2O_5 frequently returned in analyses carried out by the standard methods. It is however suggested that a variation as great as 30% would still be in keeping with the objects of soil analysis, since, setting aside inevitable errors of sampling, our knowledge of plant physiology is not yet sufficiently extensive to enable use to be made of more exact analytical data.

Table II.

Soil.		$\%P_2O_5$ by modified Denigès.	$\%P_2O_5$ by Pemberton double precipitation of molybdate.	$\%P_2O_5$ by Pemberton single molybdate precipitation.	$\%P_2O_5$ by weighing ignited molybdate precipitate.
PP 40	Peat	.130, .130, .120, .120	.134 .143		
J_9	Peat	.020, .019, .019, .018, .018	.019 .019		
J_{11}	Peat	.068, .065, .065, .062, .067 .059	.048, .048, .060, .062 .058	.091, 093	
$J_{\bar{2}}$	Peat	.027, .027, .026, .024, .023	.021, .022		
S_{10}	Heavy coastal clay with high NaCl content.	.052, .052, .051, .051, .050 .044	.034, .036, 0.39	.078, .074	
S_g	Red, highly ferrugineous clay loam	.028, .025, .025, .024, .024 .021	.028, .026, .018		.023
C_s	Loam derived from granite.	.028, .026, .025, .025, .023	.024, .024		.026
O_f	Sandy.	.017, .017, .016	—— no satisfactory estimation.		.006

Turning now to the volumetric results it is clear that with the exception of S_{10} and 0_F there is substantial agreement with the Denigès results, in the former soil there is approximately 30% discrepancy while the latter is so poor that it could not satisfactorily be precipitated. As the soils tested cover all the common Malayan types, even including S_{10} agreement may be taken as satisfactory.

The Standard Methods as Applied to Tropical Soils.

Of the three standard methods of dealing with the molybdate precipitate the magnesium phyrophosphate method is now seldom recommended, but is of interest to us because it was used in this Department up to 1920.

In most of the published analyses on tropical soils, the correctness of the standard methods appears to have been taken for granted, although the content of iron (known to affect precipitation by molybdate) is frequently very high and that of phosphorus low. When iron is considered at all it is thought to be sufficiently removed by ignition of the nitrates and subsequent boiling with dilute sulphuric acid. In the writer's experience considerable quantities of iron are dissolved by the hot acid, and on the other hand, there is danger of holding up some of the phosphate in fused particles of iron oxide if ignition is too intense. If the iron is not removed and precipitation is attempted in dilute solutions according to the old official method, the results are most unsatisfactory in our phosphorus poor soils. Precipitates are usually obtained, but microscopic examination shows them to be very impure, while the filtrate is seen to retain plenty of yellow colour.

It seems better therefore to precipitate in concentrated solution without removal of any iron or aluminium. Here again it is the writer's experience that the precipitate with ammonium molybdate is frequently very impure, and that reprecipitation is essential*, yet the usual directions for soil analyses seldom mention this, although text-books on quantitative analysis insist on it.[6]

The magnitude of the error arising from single precipitation may be seen from column 3 of Table II.

* This has been recognised by Mr. V. R. Greenstreet who since 1926 has worked with concentrated solutions and precipitated twice.

In order to compare different methods two test solutions were made up and distributed to other workers* in this Department for analysis by various methods.

Solution "A" was one of KH_2PO_4 containing 12.5 mgr. P per litre and solution "B" contained 7.4 mgr. P as KH_2PO_4 and in addition approximately 10% Fe_2O_3 and 13% Al_2O_3 as iron ammonia alum and potash alum. It was stated that 50 ccs. of A and 150 ccs. of B should be taken for each analysis, the latter quantity representing approximately 10 grs. of an average not highly ferrugineous Malayan soil.

Major C. D. V. Georgi, Ag. Agricultural Chemist with the help of Mr. Gunn Lay Teik, Assistant Analyst used the old standard magnesium method, Mr. V. R. Greenstreet, Assistant Agricultural Chemist his magnesium method, Mr. J. H. Dennett, Assistant Chemist (Soils) the old magnesium method, and that of direct weighing, while the writer used the volumetric method. Results are given in Table III, and are illuminating, especially when it is realised that solution "B" represented a rather 'easy' soil. C.D.V.G's and J.H.D's results clearly show that even with the most careful work the magnesium method is totally unreliable with single molybdate precipitation when working with small quantities of phosphorus. Even with double precipitation, the other standard methods give practically the same amount of variation as that shown by the modified Denigès method and there can be no comparison as to speed and case of working. C.D.V.G's results illustrate another pitfall of phosphorus determinations, viz. that concordant replicates are not necessarily accurate, since the disturbing factors remain constant for any one soil.

* To whom the thanks of the writer are due.

TABLE III. *Analyses of tests solutions by different methods. All values refer to mgrs. P. per litre.*

True values	C. D. V. G. Quantity	Results.	V. R. G.	J. H. D.	J. H. D.	W. N. C. B. Pemberton	W.N.C.B.	W.N.C.B. Denigès
Solution A 12.5	50 cc.	57	14.8	23.2				
	100 cc. molyb.				12.2	12.0		12.0
	50 cc.	57	15.7					11.8
	100 molyb.							12.3
	50 cc. concn.					12.8		
	to 25 cc.	60				13.6		
	50 molyb.							
	50 cc. concn. to							
	15 cc/50 molyb	60						
Solution B 7.43	150 cc. soln/	24.5	7.45		8.05	7.40	7.60	7.40
	50 molyb.						6.50	7.20
	150 cont 100/	36.0	7.85		8.40	7.75	7.40	6.80
	50							
	150 cont. 50/	43.7						
	50 molyb.							
	Molyb. soln. is 3% All ppt. were carried out by adding 10 ccs. conc HNO_3 to the soln. then molyb. and standing on steam bath for 30′ Ppts. were filtered & washed with 1% HNO_3 & dissolved in minimum 8% NH_3 & pptd. with 10cc. stand Mg. mixture Ppt. washed 2% NH_3.		150ccs. of soln. evap. to 25ccs. Few drops conc NH_3 added to 'B' till permanent ppt. just appears, conc. HNO_3 to make slightly acid, 50ccs. of 3% molyb. heat soln-cool & filter, wash with 1% HNO_3 test for elim. of Md. with ferrocy. Dissolve ppt. in 2% NH_3 if cloudy add conc. HNO_3 drop by drop till yellow ppt reappears cool, filter, wash & redissolve in 2% NH Add 2% Mg. mixture with constant stirring stand overnight filter, wash 2% NH_3 dry & ignite at 900.	As C.D.V.G.	150 ccs. Ppted in hot soln with hot HNO_3 & hot molyb. ppted. filtered on Gooch ignited & weighed direct.	50cc. of A 150 of B conc to 25 ccs. Ppted washed once re-dissolved in NH_3 reppted & washed with cold 1% KNO_3 till free to litmus, boiled with N/10 soda and xs of soda titrated N/10 H_2SO_4 with Ph. pl.	As prev. column but Ferric iron reduced with Na sulphite, P. brought down by limited ppt. of Al with NH_3.	

Other Colorimetric Methods.

Arrhenius[7] claims that the Bell-Doisy method as modified by Sjollema and Gieteleng can be applied to soil extracts. The writer has not succeeded in applying it to test solutions of iron alum and phosphate, with or without citric acid. Ferric iron does not appear to have been among the possible disturbing agents studied.

Judging from Gerdel's work[8] work on plant extracts, the aminonaphthol sulfonic acid method of Fiske and Subbarow would need at least as much adjustment to extracts as does that of Denigès, and appears to present no advantages. It was therefore not tried.

Conclusions.

1. The variation, approximately 20%, of colorimetric results on a single soil is scarcely greater than that found by skilled workers on simple test solutions using standard methods.

2. Good agreement between the colorimetric and standard methods was found in six out of eight soils of diverse types. One of the aberrant soils invariably precipitates with the greatest difficulty if at all, while the divergence in the case of the other, S_{10}, is not great enough to bring it out of its proper class viz. that of a moderately rich soil (judged by Malayan standards). As a matter of fact, the filtrates from precipitation in the case of S_{10}, J_{11} and S_9 were always rather strongly yellow and the volumetric results for all the three must lie under some suspicion. The colorimetric result for S_{10} is at least as likely to be correct as is the volumetric.

The colorimetric method then appears to be entitled to consideration on results alone, but it has two additional advantages:—

1. Manipulation is easy and can be entrusted to the semi-skilled labour of tropical laboratories.
2. It is fool-proof, errors of manipulation showing up at the end as very poor colours.

Both of these characterstics compare very favourably with the standard methods, especially when concentrated solutions must be used for the latter.

Summary.

1. It is pointed out that the direct application of the Deniges colorimetric method to acid soil extracts is frequently impossible because of ferric iron and the need of hydrogen ion control.

2. A method of reduction with zinc and hydrogen ion control with acetates, using thymol blue as an indicator is described.

3. Comparative results on different soils between the colorimetric and volumetric method are given.

4. Results of analyses by different methods and different workers of test solutions are given.

5. It is claimed that the colorimetric method, as modified, is sufficiently accurate, easy to manipulate and particularly suited to tropical laboratories.

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An Improved Method of Fusion for Soils.

J. H. Dennett.

In the usual method of fusion of soils with sodium carbonate or with fusion mixture in platinum crucibles refractory soils have been frequently encountered which do not give satisfactory intimate homogenous fluxes even after prelonged heating with a blow-pipe up to a period of two hours. It was found that much silica and sometimes sesquioxides remained in a semi insoluble condition after such fusion.

The use of caustic potash suggested itself to the writer though there seemed at first two great objections to this (a) that caustic potash attacks platinum (b) that owing to the large amount of frothing which occurs on heating caustic potash strongly, due to the evolution on hydrogen, part of the substance under examination is liable to be lost.

In order to overcome these difficulties the following procedure was adopted.

A large quantity of Potassium Hydroxide (BDH "AR" quality) is placed in a nickel basin of about four and a half inches diameter and two inches deep.

The sticks are gently fused over a blow pipe until hydrogen has ceased to be evolved after which the melt is heated strongly for a few minutes. While its contents are still liquid the basin is placed in large dessicator. When it is required to carry out a soil fusion the prepared caustic potash is re-fused and a special nickel ladle with a wooden handle is inserted in the melt for a few minutes. The ladle is made to contain just five ccs. of the fused potash. Five ccs. of the melt is transferred to a nickel crucible of about two and a quarter inches diameter and the same height. When this five ccs. has just solidified, exactly half a gram of the soil is carefully brushed into the crucible and the mixture heated in the blow pipe, gently at first and then more strongly. Some of the caustic potash tends to volatilise and recondense on the cooler portions of the crucible and a little again tends to creep up the sides, but with a crucible over two inches deep this creep ceases a considerable way from the top.

A homogenous fusion is obtained in a few minutes and the most refractory soils are complete in a quarter of an hour.

The crucible and contents are allowed to cool and when at a temperature of about 100°C are carefully placed in a 600 cc. beaker containing 150—200 ccs. of water.

The mass readily detaches from the crucible which is rinsed with distilled water and removed from the beaker. HCl is added to the beaker until solution is complete and the solution filtered to remove any carbon and oxide of nickel which may be there.

The filtrate is then treated in the usual way.

The nickel crucible is only slowly attacked by caustic potash and most nickel removed in this way does not seem to go into solution in the acid but remains on the filter paper with small amounts of carbon from the blowpipe. Any nickel which goes into solution does not affect the determination of silica, iron and alumina.

The great advantage of this method of fusion lies in the rapidity with which it is carried out, and the completeness with which the sesquioxides and silica are broken down.

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A comparison of the Robinson, International and Buoyoucos methods of mechanical analysis on non-organic soils and the analysis of such soil with and without preliminary treatment with Hydrogen Peroxide.

J. H. Dennett.

A short comparison of the above three methods was undertaken.

(1) To determine whether any differences occurred on typical soils of this country between the Robinson and International methods.

(2) The necessity of preliminary treatment with hydrogen peroxide for the non-organic inland soils.

(3) To determine whether it was possible to use the extremely rapid method proposed by Buoyoucos, (determinations of apparent density by a hydrometer at intervals of time) could be used for routine analysis locally where it is only necessary to determine the soil constituents very superficially, i.e. as to whether the soil constituents are within the limits laid down for a given crop.

The manipulation of the Robinson method of analysis is so well known that it is unnecessary to reiterate it here. In the International method it is proposed to include much of the coarse silt fraction of the Robinson method with the fine sand, and much of the fine silt with the clay. Further it is proposed that the fraction should be weighed unignited. In this connection it may be pointed out that the weighing of the fractions unignited was adopted as early as March 1927 by this Department. In practice the method of Buoyoucos (S.S. Vol. XXV, June 1928) is rather similar to the International one in as far as much of the fine silt of the Robinson method is included in clay and much of the silt is included in the sand fraction.

One objection to the proposed International method for tropical use is the fact that it is proposed to sample always

from a definite depth (10 cm) which for the clay fraction involves sampling at the end of 8 hours, a very inconvenient period with the shorter working day of the tropics. For this reason a comparison was made of clay sampled at 8 hours at 10 cm. and clay sampled at 24 hours at 30 cm.

Buoyoucos proposes the use of a special stirrer with baffles for disintegrating the soil but it has been found quite satisfactory to use an end over end shaker for this purpose.

In connection with this method an objection seems to be the proposal to estimate the sand by difference, with the idea of increasing the rapidity by avoiding the weighing of any fractions.

In each determination by this hydrometer method, the sand was determined by difference and by actual weighing.

The results obtained are given in the table.

The figures in brackets under the heading Buoyoucos are the figures for sand as actually determined by sedimentation and subsequent weighing.

It is concluded from the figures obtained that:

(1) The International method is interchangeable with the Robinson method from which it may be readily obtained by interpolation of the summation curves.

(2) as a matter of convenience it is as accurate to determine the clay fraction at the end of 24 hours at a depth of 30 cms by the International method as at the end of 8 hours at a depth of 10 cms.

(3) that it is unnecessary to use hydrogen peroxide for preliminary treatment of non-organic soils.

(4) that the method of Buoyoucos is of great utility for routine purposes for determining the general limits of the soil concerned.

(5) that it is more accurate to determine the total sand by direct sedimentation, in this latter method rather than by difference.

TABLE I.

Comparison of Robinson International and Buoyoucos methods of Mechanical anlysis.

Soil No.	Factor.	Robinson 8 hr.	Robinson 24 hr.	International 8 hr.	International 24 hr.	Buoyoucos a	Buoyoucos b
142 T	Sand	13	13	13	13	27 (20)	33 (20)
	Fine sand	12	12	19	19		
	Silt	23	23	37	37	28	22
	Fine silt	25	25				
	Clay	27	27	31	31	45	45
		100	100	100	100		
143 T	Sand	44	45	42	42	55	60
	Fine sand	18	18	24	23		
	Silt	14	13	14	14	23	18
	Fine silt	9	9				
	Clay	15	16	17	17	22	22
		100	101	97	96		
144 T	Sand	28	28	29	29	47 (45)	44 (45)
	Fine sand	17	17	24	24		
	Silt	17	18	26	25	21	24
	Fine silt	20	19				
	Clay	19	18	22	22	32	32
		101	100	101	100		
150 T	Sand	27	27	27	28	55 (51)	54 (54)
	Fine sand	29	30	37	36		
	Silt	13	14	13	12	13	14
	Fine silt	9	9				
	Clay	21	21	24	24	32	33
		99	101	101	100		
141 Sb	Sand	42	42	42	42	58 (55)	58 (55)
	Fine sand	13	14	16	17		
	Silt	3	3	2	2	3	4
	Fine silt	4	4				
	Clay	40	39	42	42	42	42
		102	101	102	103		

TABLE I.—*(Contd.)*

Soil No.	Factor.	Robinson. 8 hr.	Robinson. 24 hr.	International. 8 hr.	International. 24 hr.	Buoyoucos. a	Buoyoucos. b
149 Sa	Sand -	24	23	24	24	45 (44)	45 (44)
	Fine sand -	20	20	20	20		
	Silt -	5	5	5	4	5	5
	Fine silt -	4	4				
	Clay -	48	48	52	53	50	51
		103	100	101	101		
148 Sa	Sand -	32	32	32	32	55 (49)	55 (50)
	Fine sand -	18	19	21	21		
	Silt -	2	3	2	3	3	3
	Fine silt -	2	2				
	Clay -	42	42	44	44	42	42
		96	98	99	100		

TABLE II.

Comparison of Mechanical analysis of soils with and without hydrogen peroxide treatment.

Soil No.	——	Clay.	Fine Silt.	Silt.	Fine & Sand sand.	Remarks.
6S	Without H_2O_2	39	9	9	42	
6S	With H_2O_2	39	9	8	42	Quartzite
13S	Without H_2O_2	27	6	5	59	Phyllites
13S	With H_2O_2	28	5	5	58	areas.
14T	Without ,,	24	1	12	57	No sharp dis-
14T	With ,,	26	2	8	57	tinction in
14S	Without ,,	30	1	7	59	origin.
14S	With ,,	30	2	5	59	
16T	Without ,,	28	31	18	22	
16T	With ,,	31	29	14	26	
16S	Without ,,	27	31	21	23	
16S	With ,,	29	27	19	25	
18T	Without ,,	36	12	15	33	
18T	With ,,	36	12	15	33	
18S	Without ,,	45	12	14	25	Granite areas.
18S	With ,,	45	12	14	25	
19T	Without ,,	44	5	2	46	
19T	With ,,	44	4	3	46	
19S	Without ,,	50	3	1	44	
19S	With ,,	50	3	1	44	

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Copra Crops in Malaya.

By

H. W. Jack.

Notes on the above subject appeared in the Malayan Agricultural Journal Vol. XVI No. 8. August, 1928 and the following is written as a supplementary note in response to enquiries regarding coconut cultivation in different regions of the country.

The figures previously given were collected from thirty different estates scattered throughout the country but in the accompanying Table the figures are grouped into three regions.

The figures explain themselves and show that Lower Perak is our best producing area as far as large estates are concerned. Possibly the Benut area in Johore may be equally good but little is known of the returns in that district since the plantations are worked by small holders.

Though Province Wellesley and Perak North show a substantial improvement over the Selangor Coast area in copra production, yet the number of nuts required to produce one pikul (133 lbs.) of copra is much higher in the northern region as compared with Lower Perak and the Selangor Coast. Possibly this may simply be due to the age of the plantations for on the average the coconut plantations in Province Wellesley and Perak North are older than those in Lower Perak and the Selangor Coast.

Seasonal variation in copra production and in the number of nuts required to make one pikul of copra is noticeable in each area.

The range of seasonal variation in copra production per acre in each area is fairly similar and averages roughly 12% of the mean, the variation in Lower Perak being rather less than in the other two areas.

The range of variation in the number of nuts required to produce one pikul of copra is smaller than the range of variation in copra production per acre and varies between 2½% and 7% of the mean, being slightly more pronounced in Lower Perak than in the other two areas.

The figures for copra production per acre are probably more reliable than those relating to the number of nuts required to produce a pikul of copra because in the latter figures sources of error are numerous including errors of counting, the use of immature or over-ripe nuts and other causes.

The figures would indicate a seasonal variation of about 15% of the mean production calculated over a period of several years.

Year.	Average copra per acre.	Average No. of nuts. per acre.	Average No. of nuts per pikul of copra.
PROVINCE WELLESLEY & NORTH PERAK.—12 Estates.			
1921	8.06 pikuls.	2173	270
1922	8.53 ,,	2319	272
1923	7.64 ,,	2136	280
1924	8.57 ,,	2283	266
1925	8.55 ,,	2361	276
1926	9.86 ,,	2842	288
1927	8.47 ,,	2410	285
Averages.	8.53 ,,	2361	277
LOWER PERAK—10 Estates.			
1921	9.20 pikuls.	2336	254
1922	9.80 ,,	2536	259
1923	8.92 ,,	2107	236
1924	9.44 ,,	2210	234
1925	9.62 ,,	2211	230
1926	10.62 ,,	2590	235
1927	9.27 ,,	2286	247
Averages.	9.55 pikuls.	2325	242
SELANGOR COAST.—8 Estates.			
1921	7.34 pikuls.	1833	250
1922	6.67 ,,	1656	248
1923	6.21 ,,	1523	245
1924	6.98 ,,	1629	233
1925	7.53 ,,	1767	235
1926	8.53 ,,	2026	238
1927	8.21 ,,	2001	244
Averages.	7.35 pikuls.	1776	242

Evaporation in Rice Fields.

H. W. Jack and R. B. Jagoe.

Conflicting opinions as to the amount of evaporation which takes place in rice fields during the padi growing season and its effect on the supply of irrigation water prompted the collection of the data embodied in this note.

The facts revealed may be of interest and of value in estimating water supplies for future irrigation schemes in connection with rice cultivation and hence their publication.

The experiment was conducted at Titi Serong Padi Experiment Station, which is situated some 3½ miles from Parit Buntar, the headquarters of Krian District in the State of Perak.

A tank 20 x 20 x 20 inches was constructed and made thoroughly water tight by three coats of tar and sunk one foot in the soil on a well grassed neck of land surrounded on three sides by padi fields subject to irrigation in the padi season. Thus the position of the tank was such that it was within a few feet of the padi during the season and the rank grass growing around the tank in water logged soil made the conditions of the situation equivalent, for all practical purposes, to those actually found in the padi fields.

The other necessary apparatus, kindly loaned by the Chief Hydraulic Engineer, consisted of an eight inch rain gauge complete with measuring jar and a "Hook" depth gauge. The rain gauge was placed within 3 feet of the tank and raised so that its rim was level with the rim of the tank. The emplacement of the rain gauge and tank was surrounded by a fence of wire-netting to protect the apparatus from children or animals and there was no obstruction to the rainfall within 50—60 feet. The Titi Serong Experiment Station Staff were trained in measuring the rainfall and in the use of the depth gauge and thoroughly tested as to their accuracy before the records were commenced. Care was taken in placing the tank to assure that its sides were vertical.

The tank was filled with water at the commencement of the experiment to a depth of 1.114 feet. Whenever the depth of the water in the tank increased to within 3 inches of

the top of the tank, the depth was reduced to 1,000 feet, the depth reading being taken immediately before and immediately after the reduction and due allowance being made in calculations as can be seen from Table II which is a specimen of a complete month's records. The rainfall was measured and recorded daily at 9 a.m. and the depth gauge readings were taken at the same time on every second day except that readings on the first and last day of each month were also recorded.

Table 1 shows a summary of the figures over a full twelve month period.

TABLE I.

RAINFALL AND EVAPORATION RECORDS
TAKEN AT TITI SERONG, KRIAN

July 1927 to July 1928 (inclusive)

	Rainfall in inches.	Evaporation in inches.
1927 July 16-31.	1.85	1.833
1927 August -	5.03	5.318
,, September -	11.35	5.194
,, October -	7.84	4.516
,, November -	3.27	3.714
,, December -	8.13	6.486
1928 January -	5.92	4.612
,, February -	2.52	4.740
,, March -	5.03	4.946
,, April -	10.97	4.178
,, May -	7.08	4.716
,, June -	6.69	4.494
,, July -	4.18	3.628
Totals 1 year -	78.01	56.542
Average per mensem -	6.501	4.712

The above figures show that the rate of evaporation is fairly constant throughout the year and shows no definite relation to rainfall.

Though the greatest evaporation took place in December when there was more rain than the average, the lowest evaporation occurred in July which was a comparatively dry month the rainfall being 50% less than the average. The evaporation was higher than average in September which was the wettest month. July was the only month during the year in which the surface of the padi fields became dry, and though this condition would lead to the anticipation of increased evaporation, such did not occur, the evaporation, on the contrary, being lower than usual.

Irrigation of the padi fields normally covers the period from 1st July to the end of February so that in the padi season included in the period over which the data were collected these was a rainfall of 48.06 inches (Rainfall July 1—15 was 2.15 inches). Against this the evaporation in the same period amounted to 38.213 inches (assuming 1.800 as the evaporation July 1—15) so that only some ten inches of rainfall were available to assist the irrigation and compensate for seepage.

The season's rainfall was exceptionally low for the average rainfall in the padi irrigation season (July-February) over a period of forty years is 60.75 inches,* thus normally some twenty two inches of rainfall should be available for irrigation and to compensate for seepage and other losses.

The padi season 1928—29 is suffering from an exceptionally late drought, the padi fields still being dry up to early September but as the cultivators have postponed planting operations, the season may still experience an average rainfall.

* Records of Chief Hydraulic Engineer.

TABLE II.

Rainfall and Depth Gauge Readings. June, 1928.

Date.	Rainfall in 1/100 inches.	Depth in tank in feet.	Evaporation in feet.	Date.	Rainfall in 1/100 inches.	Depth in tank in feet.	Evaporation in feet.
May 31	173	1.223	0.016	B. F'ord	403		0.222
June 1	0	1.207	—	June 17	0	0.956	
2	0	—	0.037	18	52	—	0.017
3	0	1.170		19	29	1.006	
4	0	—	0.021	20	0	—	0.030
5	0	1.149		21	0	0.976	
6	0	—	0.032	22	0	—	0.014
7	0	1.117		23	133	1.073	
8	0	—	0.030	24	0	—	0.029
9	0	1.087		25	0	1.044	
10	360	—	0.022	26	0	—	0.021
11	0	1.365 Reduced to 1.000		27	0	1.023	
12	0	—	0.027	28	0	—	0.025
13	0	0.973		29	19	1.014	
14	38	—	0.027	30	33	1.036	0.016
15	5	0.982		July 1	0	1.025	—
16	0	—	0.026	June totals	6.69		0.374

Rainfall = 6.69 inches.

Evaporation = Rainfall + Depth difference in the month.

= 6.69 + 12 [1.207—(1.025 + .365)] inches.

+ 6.69 + 12 (1.207—1.390) inches.

= 6.69 + 12 (— .183).

= 6.69—2.196 = 4.494 inches = .374 feet.

A perusal of Table II shows that the rate of evaporation over each two day period was fairly constant around an average of .025 feet.

Moreover, the rate of evaporation is evidently not dependent solely on the rainfall. Thus on 3—4th and 21—22nd days, which were each preceded by a few days without rain, the rates of evaporation are seen to be distinctly low, contrary to expectations.

Amongst other variable factors which naturally affect the rate of evaporation wind, sunshine, temperature and cloudiness must be mentioned, but the fact remains that the general average rate of evaporation does not vary excessively from day to day and the rate of evaporation disclosed in Table II is typical of the rate in any other month of the year under review, at Titi Serong.

The calculation of the evaporation in column 4 of Table II is simply based on the difference between successive alternate daily readings, to which is added the rainfall for each period (reduced to feet). The readings, it must be remembered, are taken at 9 a.m. on each occasion, and in the padi fields there is no appreciable evaporation before this hour near the surface of the land (or water, both being almost the same) so that each reading is a record of the evaporation of the preceding day—no measurable evaporation takes place at night.

Thus the evaporation for 9-10th June in the table was

(1.087 — 1.365) feet + rainfall (3.60 inches)
= — 0.278 ,, + (3.60÷12) feet
= — 0.278 ,, + 0.300 feet
= 0.022 feet.

It is hoped to maintain these records for some years as they should be of service to engineers and others in computing the amount of water required to maintain irrigation water on rice fields and may throw some valuable light on the relation between seasons and crops.

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